

James Acker:
Dr. Sitnov -

Sergei Sitnov:
Thanks!

Hello everybody!

Forestalling our presentation is worth noting that we intensively used Giovanni for rapid multisensor analysis of the complex changes in atmospheric composition over European Russia in the period of summer wildfires in 2010. However, today we would like to demonstrate the ability to use Giovanni in studying of one important aspect of anthropogenic air pollution.

1. We are going to talk about the intra-week changes in tropospheric NO₂ over some large urban agglomerations of the world.

2. Nitrogen dioxide (NO₂) is a toxic gas whose accumulation in ambient air essentially reduces an air quality and negatively impacts human health. Being one of the two most known nitrogen oxides (NO_x=NO+NO₂) it plays a key role in tropospheric photochemistry leading to formation of tropospheric ozone and nitric acid. Due to absorption of the shortwave solar radiation (0.4-0.6 nm) NO₂ directly influences atmospheric radiative balance. Besides NO₂ is a precursor of nitrate aerosols, which also affect the radiative and thermal balance of the atmosphere.

2.1. There are both natural and anthropogenic sources of nitrogen oxides in the troposphere. At a global scale approximately 50% of tropospheric NO₂ comes from biomass burning, soil emission, lightning, and stratospheric advection. Another 50% comes from fossil fuel combustion associated mainly with human activity. This proportion may vary. In urbanized regions a contribution from anthropogenic sources noticeable prevails and besides an essential part of air pollution is due to motor vehicle emission.

2.2. The intensity of human activity often tends to stick to a weekly rhythm which is conditioned by alternation of workdays and weekends. In urban agglomerations the differences in the intensity of anthropogenic emission during a week may induce a weekly cycle in tropospheric NO₂ content.

2.3. Study of the weekly cycle in tropospheric NO₂, including its dependence on season and meteorological conditions is important for the prediction of air quality in a given location. Furthermore, the weekly cycles in radiatively active species (NO₂ among them) may contribute to inducing the weekly cycle in meteorological parameters. The weekly signals in meteorological variables were diagnosed in many regions including Central Russia (Sanchez-Lorenzo et al., 2012; Sitnov, 2011).

3. Data analysis from GOME, SCHIAMACHY and OMI satellite instruments showed increased tropospheric

NO₂ content over urbanized east coast of the USA, Western Europe, and South-East Asia. There are also a lot of places characterizing by local maxima of NO₂. One of these maxima roughly coincides with the location of Moscow agglomeration.

3.1. Due to isolated position, Moscow usually drops out from consideration of European pollution. We would like make up for this deficiency, because Moscow is the largest European megacity, with the population of 17 million people (... and also because it is our home town). It is estimated that more than 80% of tropospheric NO₂ in Moscow is due to transport exhausts. The intensity of vehicular traffic in Moscow is characterized by clearly pronounced weekly cycle.

3.2 Weekly variations in tropospheric NO₂ have been previously obtained in a number of studies. This work was largely inspired by the results of Beirle et al. (2003) and Boersma et al (2009). In its time we considered a study of the weekly cycle in NO₂ not only as research work, but rather educational work

(for us ourselves), because it was one of our first experience in studying tropospheric air pollution on the basis of satellite data.

3.3. When preparing to this workshop we conducted additional analysis of the weekly cycles in NO₂. We pursued two main goals. Firstly we would like to extract weekly cycles in tropospheric NO₂ column over large urban agglomerations including Moscow, with emphasis on the statistical significance of intra-week

differences. In this aspect, we also wanted to compare the NO₂ air pollution in Moscow with the pollution

in other major metropolitan areas on the basis of a homogeneous observational material. Second goal was

a more detailed study of the weekly cycle in tropospheric NO₂ over Moscow.

3.4. For these tasks we used obtained under clear conditions ($CF \leq 30\%$) and processed by standard algorithm the tropospheric NO₂ column densities retrieved from OMI measurements (Levelt et al., 2006; Busceta et al., 2006) in the period 2004-2009 (OMNO2G.003 product). To access the OMI data we utilized the Giovanni system (Acker and Leptouch, 2007). Giovanni allows generating the time-series of daily NO₂ data spatially averaged over territories of agglomerations and the long-term yearly mean spatial distribution of NO₂ over selected areas. It also allows downloading the original high-resolution L2 data binned into 0.25 x 0.25 degree grid at a daily basis. Weekly signals in NO₂ and long-term NO₂ spatial distributions for individual days of the week were obtained by subsequent (offline) processing of downloaded products.

4. Here you can see the location of the fifteen urban agglomerations we selected for analysis. For each agglomeration the table contains information about its population, the data collecting area, the number of days of observations and the long-term yearly mean tropospheric NO₂ column density (\pm STD of mean).

5. Here we show two examples of data collecting areas (Los Angeles is on the left and Moscow is on the right). The procedure of the formation of the NO₂ time series representing individual agglomerations was extremely simple. The territory of each agglomeration was contoured by rectangle and the data which got in this day inside the rectangle were averaged. Calculated in this way spatially averaged daily mean NO₂ values were partitioned on the individual days of the week, forming seven samples of NO₂ values representing each day of the week.

6. This figure presents the Box-Whisker plots of NO₂ values registered in individual days of the week over fifteen agglomerations. The Box-Whisker plots are based on median's distributions of the observed values and facilitate a direct comparison of the main characteristics of the distributions of NO₂ observed on different days of the week.

6.1. On each plot the weekly minimum is highlighted by green color, while the weekly maximum - by dark yellow color. The figure evidences that the weekly signals of NO₂ on different agglomerations are markedly different by amplitudes (please note the difference in vertical scales of three left and two right columns of the graphs) and here and there by phase.

6.2. The majority of weekly minima are observed on Sunday. The exceptions are two Middle East territories -

the state of Israel and Big Cairo, where weekly minima observed respectively on Friday and Saturday. This

fact obviously reflects the local religious norms and cultural traditions. Worthy of note that the distance between these territories does not exceed 400 km. With the exception of Cairo the weekly maxima of NO₂ are observed from Tuesday to Friday (in particular, over Continental Europe in Friday).

6.3. Statistical significance of the intra-week differences of NO₂ was assessed using nonparametric (rank) Kruskal-Wallis test. Red rectangles marked the days in which the mean ranks of data are significantly different ($\alpha = 0.05$) from the mean rank of data in the day of weekly minimum. It is seen that over majority of considered agglomerations the week-day tropospheric NO₂ columns are significantly different from the week-end NO₂ columns. Exceptions are Shanghai and Delhi where tropospheric NO₂ contents change little during a week, and the intra-week differences of NO₂ are statistically insignificant.

6.4. Analysis of the statistical significance of the intra-week differences in NO₂ seems rather formal procedure, since there is an obvious reason for these differences, namely the intra-week changes of anthropogenic emission. However, air pollution is defined not only by anthropogenic emission of pollutants, but also by processes of the dispersion of pollutants which depends greatly on rather irregular weather conditions and terrain topography.

7. In this figure red bars represent the long-term yearly mean values of tropospheric NO₂ columns over each agglomeration, while blue bars represent percentage peak-to-peak amplitudes of corresponding local weekly cycles of NO₂. Agglomerations are sorted by magnitude of the weekly signals.

7.1. These results evidences that there are no direct relationship between the magnitude of the weekly signals in NO₂ and mean NO₂ contents. The maximum peak-to-peak amplitude of the NO₂ weekly signal is observed in Los Angeles and reaches 64%. Despite the fact that the mean NO₂ column in Shanghai exceeds that in Los Angeles the amplitude of the weekly signal in Shanghai does not exceed 7%.

7.2. It is also difficult to trace a simple dependence of the magnitude of the weekly cycles in NO₂ on latitude

8. Right plot in this figure represent the spatial distribution of the long-term annual mean tropospheric NO₂ column in the Moscow region. It is seen that the area of high NO₂ values approximately coincides with the boundaries of Moscow agglomeration.

8.1. On the borders of the region NO₂ content is reduced from 2 to 4 times. The cleanest part of the region is the north-west, while the most polluted is the south-east. This is because the tail of Moscow's pollution is oriented in the south-east direction and extends far beyond the Moscow region.

8.2. Interestingly, that despite the fact that in the atmospheric boundary layer over the Moscow region the winds from west - south-west prevail, the tail of tropospheric NO₂ is not oriented downwind but rather reflects the surface topography, which is shown left from NO₂ distribution.

8.3. Maximum NO₂ values in the Moscow region is observed over the east side of the Moscow agglomeration.

This peculiarity has a fairly reasonable explanation, because while the vehicles are distributed over the area of Moscow more or less uniformly the industrial complex in Moscow is concentrated mainly in its eastern sector while surface winds in the center of Moscow have predominantly westerly direction.

9. Shown are the distributions of tropospheric NO₂ column over Moscow region in the middle of workweek and on Sunday. The maximum NO₂ contamination on Wednesday half as much than that on Sunday.

In both of the days the maximum contamination is observed not above the center of Moscow but rather over the east side of it.

9.1. Both of the distributions are characterized by a significant asymmetry and show a hint of a preferred orientation along the bed of the Moscow River, that is, toward lowering the terrain. This feature is more clearly observed on Sunday, when the sources of NO₂ are weakened.

James Acker:
Impressive!

Sergei Sitnov:

10. This figure shows the distributions of tropospheric NO₂ in transitional periods (on Monday and Friday NO₂ contamination starts to increase and decrease respectively). You can see that both distributions are characterized by two local maxima: one is situated within Moscow Ring Road (MRR)

and another one is situated outside of MRR.

11. This figure shows the day-to-day evolution of the distribution of tropospheric NO₂ content in the Moscow region at the beginning of the week relatively the Sunday's regime (left) and in the second half of the week relatively the Wednesday's regime (right). The effective method of tracing the cumulative changes in spatial distribution of atmospheric parameter relatively characteristic phase of studied process has been proposed in Mokhov (1985). The results show that namely the Moscow agglomeration is in a way the center of action of the weekly variability of tropospheric NO₂ in the Moscow region.

12. Given the short lifetime of NO₂ in the lower troposphere and the dominance of low sources of air pollution, the tropospheric NO₂ column represents mainly NO₂ content in the atmospheric boundary layer. It is interesting to compare the weekly cycle in OMI tropospheric NO₂ column with the weekly cycles of daytime (12:00-17:00 local time) surface NO₂ concentration in Moscow.

12.1. Three stations of Moscow Ecological Service "Mosekomonitoring" were chosen for comparison. First station which is named Balchug is located in the center of Moscow, the second one (Biryulyovo) is located in the south of Moscow agglomeration near the Moscow Ring Road close to the industrial zone. The third station (Narodnoe Opolchenie) is located in the vicinity of intersection of two high-used city streets.

12.2. Results of the comparison presented in this figure. For convenience the percentage deviations from the corresponding weekly means are presented. You can see that the weekly signals in surface NO₂ concentration in different Moscow's districts are similar. This result is probably indicative of that the weekly cycle of urban traffic is the main cause of the weekly cycle in NO₂ in Moscow, as cars, in contrast to industrial facilities are relatively evenly distributed across Moscow.

12.3. It is seen that the amplitudes of the anomalies manifesting in columnar and local NO₂ contents from Tuesday to Thursday and on Saturday are approximately the same. On the other hand on Friday the anomaly in tropospheric NO₂ column is significantly higher than the anomalies in surface NO₂ concentrations, while on Sunday and Monday an opposite interrelation is characteristic. As a consequence the magnitude of the weekend effect in NO₂ obtained using satellite data essentially exceed that obtained using ground-level data that looks rather unexpectedly due to domination in NO₂ emission the ground-level sources.

12.4. In fact, that's all we wanted to show.

13. These are our acknowledgments

14. ... and references.

15. Thanks for your attention! Are there any questions for us? But please note due to the lack of practice in speaking English very likely we will answer your questions much slower than you can type. Therefore we would be deeply and sincerely appreciate you if your question can be answered only by "yes" or "no". Thank you in advance. :)

James Acker:

Thank you, Dr. Sitnov.

Sergei Sitnov:

Thank you.

James Acker:

Two comments: one, you should study the Washington DC region too.

Sergei Sitnov:

We will try

James Acker:

Because of the dedication of our government workers, reports have cited that our air pollution is worse on the weekends.

Saturday and Sunday, because that's when everyone goes shopping.

Pavel Kishcha:

How can you explain the large dispersion of NO₂ over megacities, which is larger than the NO₂ weekly cycle?

Sergei Sitnov:

In India, for example, the staggered day off is common practice

James Acker:

May I add, New York is "the city that never sleeps" I've seen that firsthand.

One other note, there have been studies indicating more rainfall over U.S. urban areas on weekends, due to the cloud-seeding effects of pollution aerosols.

Dimitris Kaskaoutis:

in Athens, as far as I know, there is the diurnal cycle as presented over European cities

James Acker:

So we Americans are making it rain on our vacation days

Selima Ben Mustapha:

:)

James Acker:

Thank you again Dr. Sitnov - as you know, I've been trying to get you to present your research with us for a couple of years!

Sergei Sitnov:

The high NO₂ values without NO₂ weekly cycles may be due to the work of stationary industrial sources.